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JUL 80 J W RIGNEY, D M TOWNE, P J MORAN N00014-75-C-0838

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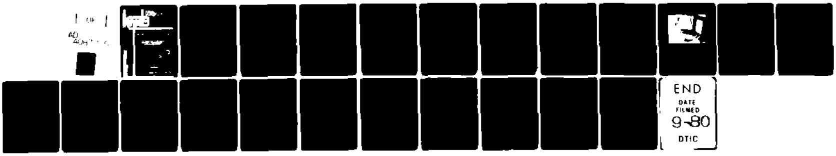

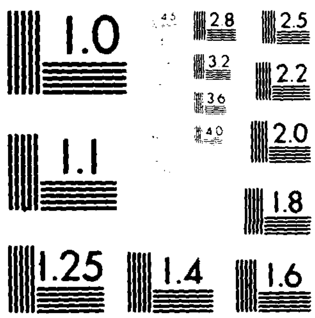

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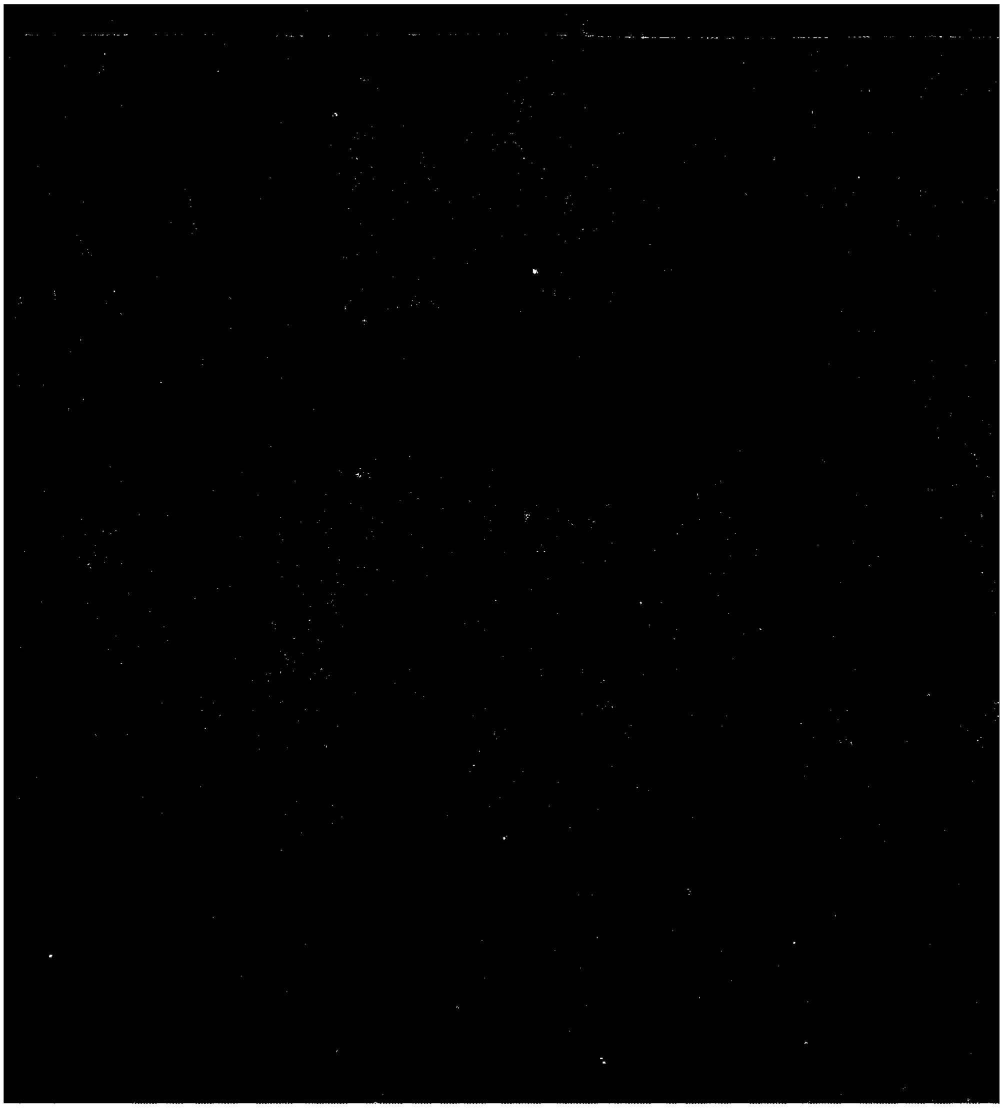

NPRDC TR 80-30 July 1980

FIELD EVALUATION OF THE GENERALIZED MAINTENANCE TRAINER-SIMULATOR: II. AN/SPA-66 RADAR REPEATER

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The Generalized Maintenance Trainer-Simulator (GMTS) is a relatively low-cost, stand-alone system for providing intensive practice in troubleshooting. To determine whether GMTS is indeed generalizable, it was applied to an entirely different target system from that used in initial testing--the AN/SPA-66 radar repeater. The data base was prepared by technical experts concerned only with supplying the specified data in the proper format and not with the nature of the GMTS program. Results

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indicated that technical experts can effectively produce the required data base, and that the technique can be applied to various types of target equipments or systems.

FOREWORD

This effort was conducted under contract with the Behavioral Technology Laboratories, University of Southern California, within Project ZN0789-PN.01, Class "A" Electronic Equipment Maintenance Training System. The purpose of this project is to develop a maintenance training system that can be applied to training for a wide variety of families of electronic equipments. The purpose of the effort described herein was to demonstrate the generalizability of the Generalized Maintenance Trainer-Simulator (GMTS). The GMTS, described in a report published by the Behavioral Technology Laboratories (Technical Report No. 89 of October 1978), was initially developed with support from the Office of Naval Research.

Appreciation is extended to personnel in Mobile Technical Unit FIVE, San Diego, who provided the facilities and students for this effort. Particular thanks are due to ETCS John B. Seagrove and to LCDR Jerry N. Layl for their support throughout the project.

RICHARD C. SORENSON
Director of Programs

SUMMARY

Problem

The Generalized Maintenance Trainer-Simulator (GMTS) is a relatively low-cost, stand-alone system for providing intensive practice in troubleshooting. The GMTS can be applied to any target equipment or system by compiling the particular effects of indicators in various configurations and modes, and by preparing microfiche images of the equipment in a multitude of normal and abnormal states. To date, the generalizability of the GMTS has been tested using a Fleet Communications System, with generally effective results.

Purpose

The purpose of this effort was to demonstrate that (1) the system is general and can deliver training and simulation on any target system that is properly documented, and (2) its data base can be prepared by technical experts who are experts in the behavior of the target system and the data base format but are not concerned with the nature of the GMTS program.

Approach

GMTS was applied to an entirely different target system than that used in the initial field test; namely, the AN/SPA-66 radar repeater. The data base was prepared by two technical experts who were concerned only with supplying the specified data in the required formats. A relatively short field test followed, involving 10 subjects, each attempting to isolate 33 simulated malfunctions over a 16-hour period. Following this practice phase, the students were tested using an actual AN/SPA-66 with actual inserted malfunctions.

Results

1. As with the first field test, results were generally positive, especially in relation to success in the test phase using actual equipment. Owing to the small sample size, however, this field test is primarily of value for assessing the success with which technical content experts can apply GMTS to a wide range of target systems.

2. Subjects were generally satisfied with system characteristics.

Conclusions

Equipment experts can effectively produce the data base required by GMTS to drive a comprehensive training situation. Further, the generality of the technique was demonstrated by applying it to a second distinct and dissimilar target system.

Recommendations

It is recommended that the development of the GMTS be continued, and that its effectiveness in providing training in the classroom/laboratory situation be evaluated over an extended period.

CONTENTS

INTRODUCTION

Problem and Background

The Generalized Maintenance Trainer-Simulator (GMTS) is a relatively low-cost, stand-alone system for providing intensive practice in troubleshooting. While GMTS includes both hardware and computer software, the computer programs and associated data base represent the essence of the GMTS concept. This concept can be applied to any target equipment or system by compiling the particular effects of indicators in various configurations and modes, and by preparing microfiche images of the equipment in a multitude of normal and abnormal states. This information, contained in a data base dedicated to the equipment to be simulated, can be used to generate and present meaningful interactions with each individual student.

The GMTS program does not contain data specific to any simulated system; rather, the trainer-simulator is considered to be generalized. This generality was first demonstrated in 1978, when the GMTS was applied to the Fleet Communications System, a large multi-equipment system for radio communication, with generally effective results.[1] In that test, 20 class "A" school students worked on 35 simulated troubleshooting problems concerning UHF communications. The data base used was assembled primarily by the personnel responsible for programming GMTS.

Purpose

The purpose of this effort was to demonstrate the validity of two fundamental premises of the GMTS concept:

1. That the system is general, and can therefore deliver training and simulation on any target system that is properly documented.

2. That such documentation or data base can be prepared by technical personnel who are experts only in the behavior of the target system and the format of the required data base, but are not concerned with the nature of the GMTS program.

GENERALIZED MAINTENANCE TRAINER SIMULATOR: COMPONENTS AND FUNCTIONS

Hardware Components

The particular hardware components of the GMTS configurations employed are listed in Table 1. It should be noted that these components are somewhat secondary in importance to the more fundamental aspects of program design and data base structure.

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[1]Rigney, J. W., Towne, D. M., King, C. A., and Moran, P. J. Field Evaluation of the Generalized Maintenance Trainer-Simulator: I. Fleet Communications System (Technical Report No. 89). Los Angeles: University of Southern California, Behavioral Technology Laboratories, October 1978.

Table 1

GMTS Hardware Components and Functions

Component	Manufacturer, Model Specifications	Function
CRT	Part of IMLAC PDS-1 minicomputer (30 lines of 72 characters)	Displays dynamic information about a simulated problem, such as possible malfunctions logically suspected, previous student actions, and directions related to proceeding with a simulated troubleshooting problem.
Microfiche Viewer	Image Systems Model 201, 54,000 image capacity (900 fiche x 60 images/fiche)	Under computer control, displays color images of the target system, back-projected on a 14" x 14" screen. Data base for AN/SPA-66 required 8 fiche (451 images).
Touch Input Device	SAC Graf/pen, Model GP-3 with 14-inch X and Y axes	Provides student entry capability. Student actions, such as setting switches, viewing indicators, replacing circuits, are made by touching the touch-pen to the desired location on the projected image or the command-menu (see Figure 1).
Computer	IMLAC PDS-1 16-K minicomputer	Receives, interprets, and processes all student actions and drives response devices (CRT and microfiche) via the GMTS program and target system data base.
Mass Data Storage	AED 2500 floppy disk drives	Contains GMTS program, target system data base, and accumulated data regarding individual student progress.
Interface	Cybernex (custom design)	Provides Graf/pen-to-computer and computer-to-microfiche data transfer.

Operating Characteristics

A simulated troubleshooting problem in GMTS involves the following:

1. Presentation of initial "complaint"--A brief statement that describes the major abnormal function, typical of that which might be received from the equipment operator, is displayed on the CRT. Typical complaints are (a) range rings missing, (b) target video abnormal, and (c) no sweep in centered operation.

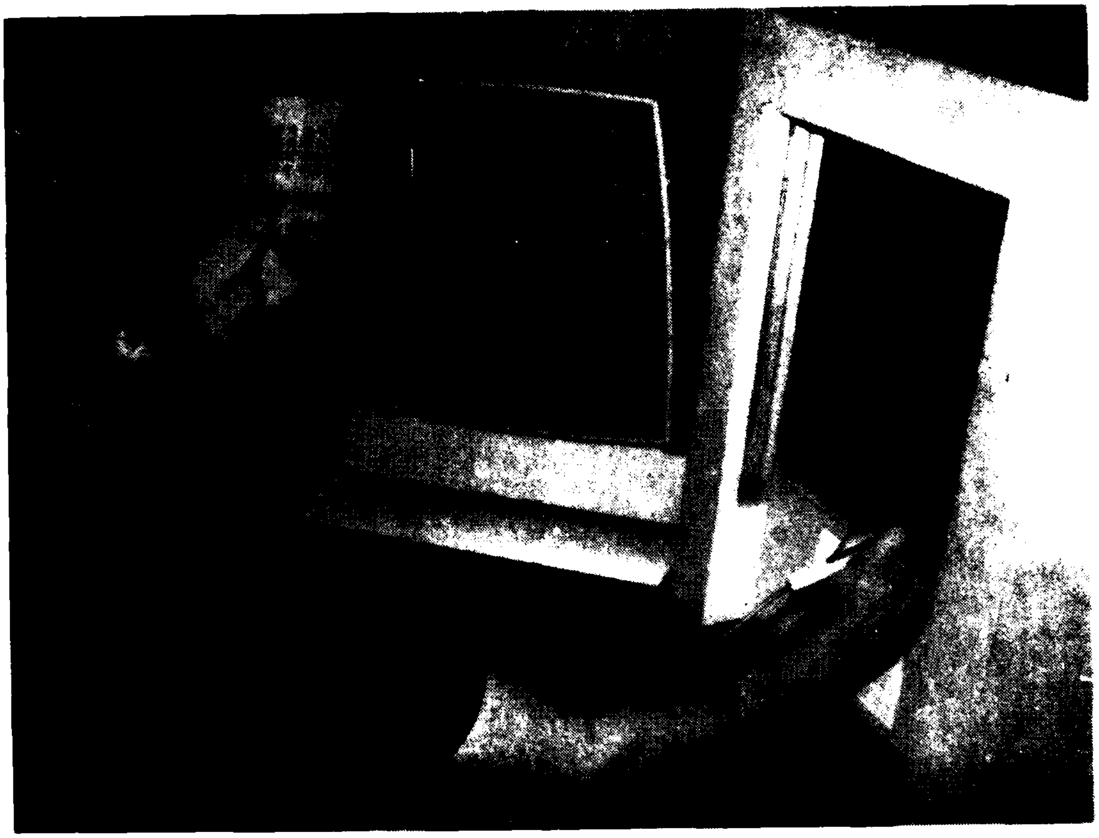

Figure 1. The student interacts with the GMTS by touching the touch-pen to the desired location on the projected image or the command-menu.

2. Symptom gathering--The student "operates" the target equipment, including associated test equipment, by touching the pen to desired switch settings and observing the displayed indications. The computer program determines, from the data base, which image reflects the front panel in the desired setting and also presents the indicators as they would appear in that mode for the simulated malfunction. It automatically presents this image after sensing the simulated switch setting. In a similar manner, the student can point to subsections of an equipment, or to test equipment, and receive a close-up image of the selected unit in its current set-up. The student can easily inspect any area of a large system by simply pointing to the area of interest and can operate the simulated system by reaching toward a switch to be set and touching the desired setting, as illustrated in the earlier report.[2]

3. Replacement--The student may replace any of the possible fault areas by entering the fault area number. GMTS does not indicate whether this restores the equipment or not; instead, it records the fact that a replacement was made, and, if the actual malfunction was located, makes the adjustments necessary to provide only normal indications for the remainder of the problem.

[2]See footnote 1.

4. System state assessment--Identical to symptom gathering, but performed to determine if the equipment has been restored to normal operation. If abnormal indications are found, the student returns to Step 2 above, or gives up.

5. Termination--When the student believes that the system is restored to normal operation, or he cannot locate the fault, he indicates that he is done. If the fault was corrected, GMTS so indicates and begins a new problem. If the fault was not replaced, GMTS asks the student if he wishes to continue. The student may then either give up or he may continue searching for the problem.

In any case, GMTS records the termination state of each problem, the number of replacements made, the time devoted to the problem, and whether or not the student declared the problem solved when it was not solved.

GMTS Data Base

As noted previously, the data base from one target system to the next varies in content, but is of a constant format. The data base for any system includes the following elements:

1. Alphanumeric data representing names of switches, switch settings, fault areas, and subelements (equipment, units, modules, boards, etc.).

2. Numeric data relating the symptom at each indicator to the switch settings and malfunction state of the system.

3. Numeric data providing an index to the microfiche images (image numbers corresponding to each subelement under each possible condition).

4. Microfiche, containing images of the target system in all conditions required by 2 above.

5. Numeric data representing the X-Y coordinates of switches, settings, and subelements on projected images (these are obtained from a utility program that generates the coordinates when the data base preparer touches the microfiche projection screen with the touch-pen).

APPROACH

Since a major objective of this effort was to demonstrate the generality of the GMTS, a data base for a completely different system--the AN/SPA-66 radar repeater--was implemented, without making any changes to the GMTS program. As opposed to the Fleet Communications System, the AN/SPA-66 radar repeater is an indicator group that operates in conjunction with other radar equipment to provide a central display of radar returns. The repeater consists of six functional sections: timing, range-azimuth, sweep control, sweep generation, display, and power supply, packaged into one equipment. The display can be either centered or off-centered, depending upon front-panel settings.

Subjects

Participants consisted of 10 Navy electronics technicians, who responded to a Pacific Fleet request from Naval Mobile Technical Unit 5 in San Diego, California. Responses to the attitude questionnaires (see appendix) provide further data on subject background.

Schedule and Instructional Sequence

The instructional period consisted of approximately 4 hours per day, per student, for 4 days. During this time, each student completed 33 problems. As shown in Table 2, which presents the actual malfunctions simulated and the instructional sequence, the problems were divided into two groups--27 problems affecting the equipment in "centered" operation and 6 affecting off-centered displays. The first problem in each group presented the equipment in normal operation, allowing the student to gain familiarity with controls, switches, and normal indications related to the particular group. The equipment sections were covered in a logical, functional sequence, rather than according to difficulty.

Before starting an instructional section, the student was required to read about the section in a specially prepared instructional manual--the regular U.S. Navy AN/SPA-66 maintenance manual (NAVSHIPS 0967-LP-008-60109) with information not necessary for troubleshooting deleted. An input-output analysis of equipment testpoints was highlighted in order to ease troubleshooting. After the student finished the required reading, he would proceed to troubleshooting problems for that section. The selection and order of problems within a given section were chosen to maximize the student's understanding of the section's circuitry and functional relationships. Practice problems consisted of a mixture of different problems from all sections.

Testing

The test consisted of four representative problems (Table 2), each inserted into an otherwise normally operating AN/SPA-66 repeater. The students were then timed as they worked on the actual equipment. In some cases, it was necessary to instruct the student on oscilloscope operation prior to the testing period.

Table 2

Instructional Sequence of Training Sections

Section	Problem Number	Problem Title
		Centered Circuits
Normal Operation	1	Normal Operation
Power Supply	2	Power Supply IFL 1
Timing	3-7	A9 Pulse Shaper A9 Sweep Gategen A8 PRF Sawtooth Gen. A8 Rng Trng. Gen. A7 Time-share Output
Sweep Control	8-10	A4 5 KC Chopper A3 Drivers A5 Video Sweep Bearing Detectors
Sweep Generation	11-13	A14 Emitter Follower and Bias Circuits A11 Cascade Differential Sweep Circuits A12 Cascade Differential Sweep Circuits
Display	14-17	A10 Range Strobe Pulse Generator A6 Range Ring Gating Circuits 1A24A1 Video Mixer and Output Circuits 1A24A2 Intensity Gate Generator
Practice (all sections)	18-27	Power Supply 1K9 A9 "T Off" Circuits A8 Range Sawtooth Generator A7 Time-share Output Circuits A4 Sample Detector Drivers A7 30ms Multivibrator A14 Emitter Follower and Bias Circuits A10 Range Strobe Sawtooth Generator A6 Countdown Chain A6 Range Ring Pulse Generator
Test Problems	34 35 36	A9 Sweep Gate Generator A7 Time Share Gate Generator A4 10KC Oscillator
		Off-centered Circuits
Normal Operation	28	A5 N-S Manual DRA Off-center Detector
Sweep Origin Off-centered	29	A5 Bearing and Off-center Circuits
Cursor Off-centered	30	A6 E-W AEW Off-centering Circuits
Practice (all sections)	31-33	A11 E-W Off-centering Circuits A5 AEW Detectors A12 N-S Off-centering Circuits
Test Problem	37	A5 N-S Manual DRA Detectors

RESULTS

GMTS Training-simulation

All students completed the 33 GMTS problems within the 4 days of instruction. None encountered discernable difficulties in transitioning from GMTS to the test on the actual equipment.

Figures 1 and 2 show the mean times required for the students to complete the practice problems and related test problems for the centered and off-centered circuits respectively. One standard deviation above and below the mean is indicated by vertical hash marks, indicating that 68 percent of the students completed problems in that section within the designated interval.

Since the sample size is extremely small (N = 10), and problem difficulty was not a controllable variable, these results are only general indicators of training effectiveness.

The mean times to solve the test problems do not include the additional time required to insert the malfunction into the AN/SPA-66 repeater, or to remove it and restore the equipment. These tasks averaged approximately 30 minutes per problem total additional time.

In addition to extremely small sample size, the following factors must be considered regarding these results:

1. Since the students could not be screened according to previous experience, there were large variances in problem completion time.

2. Problem difficulty was not controlled. Thus, mean solution times were affected by difficulty of the particular malfunction, complexity of its section, and the order in the problem sequence (the sequence of problems and related equipment sections was chosen to provide logical treatment of functional characteristics).

3. The maintenance manual employed was taken directly from actual technical documentation rather than being developed for the purpose of providing equal treatment of each equipment section.

Attitude Questionnaire

The questionnaire completed by the subjects is given in the appendix, along with a compilation of responses to each item. This provides a profile of the 10 subjects, as well as an indication of their reaction to this approach.

In general, subjects found GMTS to be enjoyable, effective, easy to use, and accurate. Sixty-six percent held "very favorable" attitudes concerning GMTS characteristics; 30 percent, "favorable"; and 4 percent, "neutral." Most subjects learned to use GMTS in approximately 30 minutes, and would allocate their own practice times at approximately 2/3 on GMTS and 1/3 on the actual equipment, if given the opportunity.

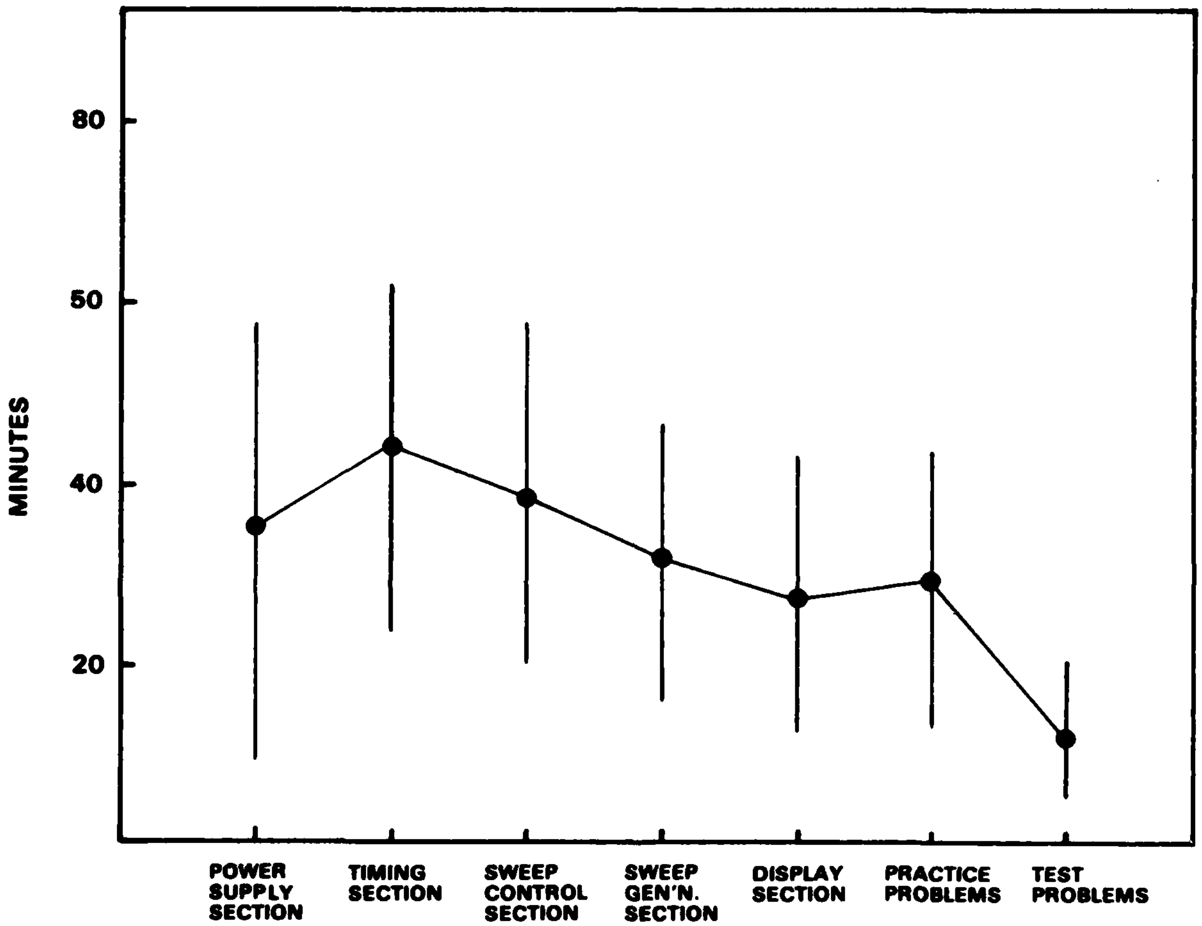

Figure 1. Average solution times per problem, centered circuits (means and standard deviations, N=10).

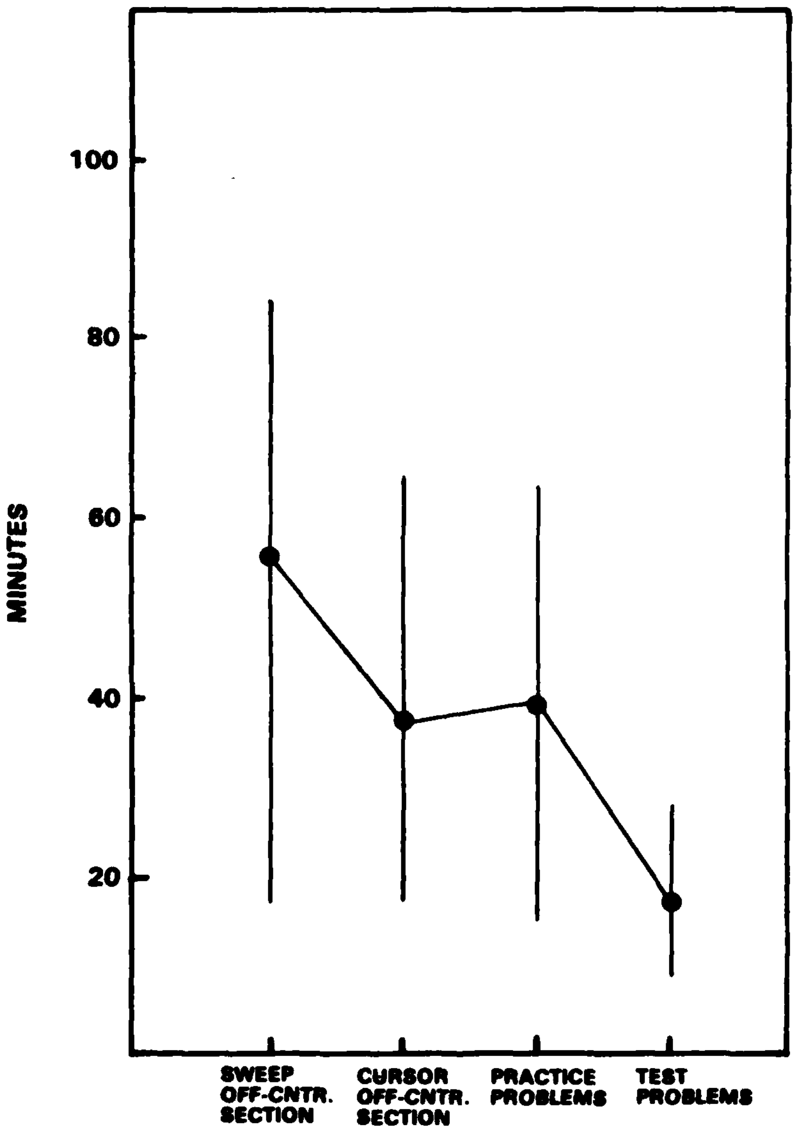

Figure 2. Average solution per problem, off-centered circuits (means and standard deviations, N=10).

CONCLUSIONS

This study demonstrated that equipment experts can effectively produce the data base required by GMTS to drive a comprehensive training-simulation. Further, the generality of the technique was partially demonstrated by applying it to a second distinct and dissimilar target system.

The data provided by this study further substantiates assertions made regarding some particular advantages of training on a general-purpose simulator to that on the actual equipment. Specifically, GMTS offered a range of troubleshooting problems and instructional support that would not be available using an actual AN/SPA-66.

Finally, it appears from the limited data, that troubleshooting skills derived from GMTS training can be transferred to the actual equipment.

Based on responses from the subjects, GMTS training and training on the actual equipment can offer a complementary and practical combination.

RECOMMENDATIONS

Both of the studies completed to date have been short-term studies using a single GMTS unit in an experimental environment. The effect of the GMTS as a replacement for actual equipment now needs to be evaluated over a longer period in a controlled study wherein the performance of students using the GMTS can be compared directly to the performance of those using actual equipment. Further, an implementation of the concept should be demonstrated using the more advanced technology provided by the current series of stand-alone microcomputers. An implementation using essentially off-the-shelf components is underway at the present time.

In addition to the above, a number of research questions should be addressed. Data base preparation requires the exercise of considerable diligence and the expenditure of a significant number of man-hours per hour of instruction. Procedures for facilitating preparation, perhaps including automation of the process, need to be explored. In addition, the data base should be formatted in a highly transportable language, such as Pascal or the forthcoming tri-service standard (Ada), so that it can be implemented on different computers.

APPENDIX

SUMMARY OF STUDENT RESPONSES
(N = 10)

1. **Name** ______________________ **Student No.** __________
Last, First, Initial

2. **Rating**

ETSN	ETR3	ETR2	SD2
2	5	2	1

3. **Number of years experience in fleet electronics**

≤1	2	3
5	3	2

4. **AESD Student** None
Yes/No

5. **Education level**

12	13	14
5	3	2

Years 1-16

6. **Are you a graduate of:**

   (a) **Naval Electronics 'A' School.** YES 10
   Yes/No

   (b) **Naval Electronics 'B' School.** None
   Yes/No

   (c) **Approximate number of 'C' Schools attended.** Mode = 0 range 0-5

7. **Previous experience on SPA-66 Radar repeater** Mean = .9 yrs. range 0-15
Yes/No Yrs.

8. **Previous experience on other radar repeaters.** Mean = .8 yrs. range 0-2
Yes/No Yrs.

1. Compared to other learning experiences on similar subject matter, my experience with GMTS was: (circle the letter in front of one choice in the following sequence of questions).

8 a. Much more enjoyable
2 b. More enjoyable
c. About as enjoyable
d. Less enjoyable
e. Much less enjoyable

2. As a technique for learning and practicing systems troubleshooting, GMTS was:

9 a. Very effective
1 b. Effective
c. Both effective and ineffective
d. Somewhat ineffective
e. Very ineffective

3. GMTS was:

5 a. Very easy to use
5 b. Easy to use
c. Neither easy nor difficult to use
d. Difficult to use
e. Very difficult to use

4. The initial instruction given on how to use GMTS was:

1 a. Much more than adequate to my needs
3 b. More than adequate to my needs
6 c. Adequate to my needs
d. Less than adequate to my needs
e. Much less than adequate to my needs

5. It took me the following time to learn to use GMTS:

9 a. About 1/2 hour
1 b. About 1 hour
c. About 1-1/2 hours
d. About 2 hours
e. More than 2 hours

6. I found the introduction material to be:

9 a. Very useful
1 b. Useful
c. Not especially useful
d. Not useful
e. Not at all useful

7. The introduction should be:

1 a. Greatly expanded
2 b. Expanded
7 c. Left as it is
d. Reduced
e. Greatly reduced

8. Setting switches by use of the touch-pen was:

3 a. Very easy
5 b. Easy
2 c. Neither easy nor difficult
d. Difficult
c. Very difficult

9. The microfiche slides were:

7 a. Very easy to interpret
2 b. Easy to interpret
1 c. Both easy and difficult to interpret
d. Difficult to interpret
e. Very difficult to interpret

10. The material in the maintenance manual was:

7 a. Very useful
3 b. Useful
c. Slightly useful
d. Not very useful
e. Not at all useful

11. The symptoms exhibited by GMTS for the malfunctions were:

3 a. Very accurate
7 b. Generally accurate
c. Both accurate and inaccurate
d. Generally inaccurate
e. Very inaccurate

12. For me, the problems were:

a. Much too difficult
b. Too difficult
10 c. About the correct difficulty
d. Too easy
e. Much too easy

13. If I had 10 hours to practice system troubleshooting, I would divide my time as follows between GMTS and the actual SPA-66 Radar Repeater:

6.5 hours on GMTS

3.5 hours on actual equipment

Total 10

14. Prior to this course I was:

- a. Very familiar with the SPA-66.
- 3 b. Familiar with the SPA-66.
- 2 c. Somewhat familiar with the SPA-66.
- 3 d. Not very familiar with the SPA-66.
- 2 e. Not at all familiar with the SPA-66.

15. If I could, I would have:

- 1 a. Used GMTS much longer
- 2 b. Used GMTS longer
- 7 c. Stopped using GMTS about when I did
- d. Stopped using GMTS sooner
- e. Stopped using GMTS much sooner

We are interested in your comments, especially if you have ideas, criticism, etc., which this questionnaire will not otherwise reflect:

My Comments: List and frequency of common comments:

4 GMTS was an effective method to teach troubleshooting the SPA-66

3 Methods of instruction were very effective

2 GMTS should be used on other equipments

2 Could do more problems using GMTS than would be possible on the actual equipment

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